

The Futures Premium and Rice Market Efficiency in Prewar Japan

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Abstract: This paper studies the interrelation between spot and futures prices in the two major rice markets in prewar Japan from the perspective of market efficiency. Applying a non-Bayesian time-varying model approach to the fundamental equation for spot returns and the futures premium, we detect when efficiency reductions in the two major rice markets occurred. We also examine how government interventions affected the rice markets in Japan, which colonized Taiwan and Korea before World War II, and argue that two types of government intervention had different consequences in association with the rice imports from the colonies. One intervention suppressed the rice price allowing imported rice deliverables in the futures exchanges and reduced the efficiency of the rice markets. Another intervention balanced the differences in rice varieties from the inland region and the colonies, which promoted japonica rice cropping in the colonies and ameliorated the disruption.

Keywords: Rice Futures Markets; Futures Premium; Market Efficiency; Non-Bayesian Time-varying Model Approach.

JEL Classification Numbers: N25; G13; C22.

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1 Introduction

Price risks associated with lean crop yields, wars, and economic crises are persistent problems. Historically, global futures markets have been established to hedge such risks. In general, a futures market is characterized as a well-organized forward market of a commodity, and it provides a fine index of the expected commodity price. However, it is not clear how and to what extent government interventions affected both the futures and physical markets of agricultural commodities of colonized countries before World War II.

Steam locomotives and steamships became popular after the Industrial Revolution. These new transportation channels provided mass, high-speed transportation. They also enabled rapid and expanding commercial transactions including foreign trade. However, the expanding trade with more distant locations exposed traders to greater price risks. Accordingly, futures exchanges were established in the 19th century, for example, in Chicago (founded in 1848), Frankfurt (founded in 1867), New York (founded in 1870), and London (founded in 1877) (see Kaufmann (1984, p.11)). The futures exchange in Japan was established in the early 18th century.

The Tokugawa Shogunate, which was formed in 1603, enjoyed a long period of rule throughout Japan and stabilized the internal economy and civic order. The stability of the 17th century allowed authorities to improve transportation infrastructure such as roads, coastal routes and harbors. The infrastructure improvements increased trade among remote locations. The Shogunate also permitted shipbuilders to build large merchant vessels under a stable military in 1638. This permission enabled mass transportation. As a result, Japan experienced expanding trade among remote locations beginning in the 17th century. While rice trading became more active, rice merchants faced greater price risk because of changing commercial transactions. Accordingly, the Shogunate certified the *Dojima Kome Kaisho* (i.e., the Osaka-Dojima rice exchange) in 1730. Rich historical data and substantial literature are available for the Japanese rice markets from the Tokugawa period.

Miyamoto (1988), Schaede (1989), Kato (2001), and Takatsuki (2012) focus on the Osaka-Dojima rice futures market for the Tokugawa period (1603–1868). The authors investigate the historical performance of the rice futures market using statistical techniques. For more econometric handling of the same data, Ito (1993), Wakita (2001), and Takatsuki (2008) examine the fundamental equations of rice futures premiums while Hamori et al. (2001) apply an error correction model to the rice futures premium. Kakizaka (2012) conducts some unit root tests for spot and futures rice prices. The empirical results crucially depend on sample data periods; there is no consensus concerning whether the market was efficient in the sense of Fama's (1970).

While the Osaka-Dojima rice futures market only traded domestic rice in the Tokugawa era, the market traded import rice and domestic rice after the Meiji era. This difference resulted from severe restrictions on foreign trade and international relationships, called *Sakoku*, enforced by the Shogunate. The isolation policy started from the middle 17th century. Consequently, imported rice did not circulate in the domestic market until the mid-19th century. We consider the consequences of the difference between the two eras with respect to rice futures.

Japan concluded the Treaty of Amity and Commerce with the US, the UK, the Nether-

lands, Russia, and France in 1858 and opened the ports in 1859. The Meiji government declared a new regime in 1868. Discarding the isolation policy of the previous authority, Japan adopted Western technologies and improved the modern transportation infrastructure for steam locomotives and steamships. The resuming of foreign trade and the introduction of modern infrastructure resulted in an increase in commercial transactions in Japan. Commodity futures trading also became more active. Particularly, rice was a major commodity in the futures markets. Rice futures were traded in the two major commodity exchanges in Tokyo and Osaka. Taketoshi (1999) examines the market efficiency of the Tokyo rice futures exchange using the Fama and French's (1987) model. Shizume (2011) studies the rational expectation formation of rice futures in the Osaka rice futures exchange using the Hamilton's (1987) model. Nakanishi (2002) and Koiwa (2003) discuss the evolution of the two major rice futures exchanges considering the correlation of price and shares of trade changes over time. However, the previous literature has paid little attention to the characteristics of the rice market in prewar Japan: Japan's dependency on rice from its colonies.

When Japan won the Japanese-Sino War, during the years 1894 to 1895, the country gained Taiwan as the first Japanese colony. In 1910, Japan annexed the Korean peninsula. In prewar Asia, Japan was the only country possessing colonies. It had consumed colonial rather than foreign products since the government had decided to save specie money under the gold standard. Particularly, Japan imported food and resources from its colonies: rice, sugar, soybean, and salt. It was one of the countries managing the foreign and colonial trading policies outlined above. Since the 17th century, European countries owned colonies in the Americas, Africa, and Asia. The colonies supplied the needs of foods and resources in the home countries. However, Japan depended on its colonial trade to a greater extent than European countries (see Okubo (2007) and Hori (2009, pp.72–75)). In particular, domestic rice production had not met increasing demand from domestic consumers because of rapid industrialization and urbanization since the 1890s. Japan compensated for the insufficiency in domestic rice supply with the import of colonial rice. Nevertheless, there are few studies that focus on how the growth of colonial trade affected the function of commodity markets in prewar Japan.

Ito et al. (2014a) show that the efficiency of each of the Tokyo and Osaka rice futures markets varied over time using a non-Bayesian time-varying VAR model. The authors argue that the efficiency of the rice markets was affected differently by two types of government intervention: allowing imported rice deliverables in the futures exchanges and promoting japonica rice cropping in the Japanese colonies. However, the authors do not discuss the interrelation between the two major rice markets for spot and futures rice prices.

This paper studies the interrelation between spot and futures prices in the two major rice markets in prewar Japan from the perspective of market efficiency. We then examine how government intervention disrupted and ameliorated the efficiency of the spot and futures rice markets. Our examination has four components. First, we estimate the well-known equation for spot returns and futures premiums and test its parameters to examine whether the markets were efficient. Second, we test the parameter constancy in the estimation procedure. Third, if there is doubt, we estimate the parameters of the equation at each period assuming that the two major rice markets are confronted with continuous

structural change. At this stage, we use a non-Bayesian time-varying model approach, which allows us to estimate the parameters and to conduct statistical inference from a residual-based bootstrap technique (see Ito et al. (2014b, 2016)). Fourth, we detect when the rice markets were inefficient and investigate the possibility that government interventions in the rice markets affected market efficiency. Then, we historically investigate how government interventions disrupted and ameliorated the efficiency of the rice markets.

This paper is organized as follows. Section 2 provides a short historical review of rice markets in Japan. Section 3 presents our methodology with respect to our non-Bayesian technique for a linear regression equation with time-varying parameters. This section also provides statistical inference for the above time-varying parameters based on a residual-based bootstrap method. Section 4 describes the data on the rice futures markets in prewar Japan. Section 5 shows our empirical results and their historical interpretation. Section 6 concludes.

2 A Historical Review of the Rice Markets in Japan

This section explains the crucial role of rice in Japanese history: rice as the staple diet component, a rice-based tax system, the development of rice futures, the import and export of rice, and government interventions in the rice markets.

Rice cultivation was introduced from China and began in Japan in the Yayoi period, from 400 BC to 200 AD (see Imamura (1996, pp.127–130)). Cultivation was first diffused in western Japan and then spread throughout the country. Rice cultivation changed the Japanese principal diet from nuts, such as acorns, of the prehistoric diet to rice.

Since then, rice production has assumed a significant role in the Japanese economy. With respect to tax systems, successive authorities in Japan often imposed a tax on rice even before Toyotomi Hideyoshi, a preeminent lord, first unified Japan. However, he introduced a nationwide system of tax called *kokudaka-sei*, which imposed taxes depending on rice crop yields. A civil war began in 1598 after Hideyoshi's death. Tokugawa Ieyasu, the victor, became the first *Shogun* in 1603 and ruled Japan. The Tokugawa family maintained their position of *Shogun* in a patrimonial system called the Tokugawa Shogunate until 1867. Both rice production and population increased with fluctuations under this stable administration.

Within the Tokugawa period (1603 to 1868), the Shogunate and clan governments (feudal lords) followed Hideyoshi's tax system. The authorities collected a large portion of their taxes from rice. At that time, rice was pseudo money for the tax system. Samurais' salaries were paid in money form as well as rice. Japan reached a turning point in its monetary economy. The authorities were forced to expend government payment and debt repayment using specie money. Moreover, the government borrowed increasing amounts from wealthy merchants in Osaka, the center of the Japanese economy. At the same time, the authorities needed to transform collected rice into money. Accordingly, the authorities sent the collected rice to Osaka using sailing coast liners. At this time, more specie money was in circulation than had been in circulation before the Tokugawa period.

The monetary economy advanced during the early 18th century and was partly dependent on the weather, which affected rice production. Rice traders during the 18th century

faced increasing price volatility risks because the Japanese rice industry depended on climatic conditions, expanding trades among remote locations, and increasing transaction size. Both authorities and rice brokers, the sellers and the buyers in a rice market, faced the risk of price fluctuations. The rice brokers began futures dealing in Osaka to hedge the price volatility risks. Tokugawa Shogunate certified the *Dojima Kome Kaisho* (i.e., the Dojima rice exchange) in 1730. The price in the Dojima rice exchange provided a standard for western Japan and balanced rice prices nationwide (Miyamoto (1988, pp.402–403) and Takatsuki (2012, pp.315–368)).

When the Meiji government declared a new regime in 1868, Tokugawa Yoshinobu, the last *Shogun*, initiated a civil war. Because the internal conflict ended in 1869, the new government had consolidated its foundation. From then on, the Japanese economy developed in the Meiji period (1868 to 1912). In 1869, the Meiji government forbade the Dojima rice exchange to trade in futures because it considered the activity to be gambling. Rice traders requested the government to reopen the futures market. The government permitted the Dojima rice exchange to resume futures trading in 1871 (see Tsugawa (1990, pp.26–40)). In the same period, rice traders in Tokyo sought to establish another rice futures market, and two rice futures markets were set up in Tokyo. First, Hachirouemon Mitsui, a wealthy merchant in Tokyo, began futures rice trading through his company, *Bouekishousha*, in 1871. *Chugai Shougyo Kaisha*, supported by representative merchants in Kagoshima, began rice futures trading in 1874. These two rice exchanges in Tokyo were unified in 1883 and were renamed Tokyo *Kome-Shoukaisho* (i.e., the Tokyo rice exchange) (see Tokyo Grain Exchange (2003, pp.27–36)). The two major exchanges in Tokyo and Osaka have led the rice futures markets in prewar Japan since the 1880s.

At the same time, the government was directly promoting rice exports to earn foreign money. The rice market in Japan changed drastically along with increasing rice exports during the 1880s. Japan opened its ports to foreign trade in 1859. By the early 1880s, Japan was exporting primary commodities, particularly tea and silk, to Europe and the US. In the late 1880s, the volume of rice exported to Europe and the US increased rapidly because of an upturn in trade terms. The upturn was a consequence of the relatively lower price of silver than gold at that time when Japan continued to adopt the silver standard system until 1897 (see Omameuda (1993, pp.18–20)). However, the terms of overseas rice trading changed again in the 1890s.

Since the 1890s, rice demand in Japan had exceeded its supply. Japan suffered from a chronic shortage of rice after the 1890s. Rice imports exceeded exports after the 1890s. In the 1890s, Japan imported rice from the Southeast Asian countries and Korea. However, beginning in the 1900s, rice imports from the Japanese colonies increased. Imported rice from the colonies was of a different variety than domestic rice. The former was an indica variety, and the latter was japonica, and each variety has a different texture and taste. When rice was shipped from Korea, farmers and brokers mixed sand, stones, and other trash into rice sacks to cheat their trading partners by commodity weight. The rice traders dealing in the Korean rice had to make arrangements to polish the rice with sand and stones. To this end, rice traders prepared dedicated milling machines that could decontaminate the sand and stones from the Korean rice. Particularly, the rice traders who had the milling machines for the Korean rice clustered in Osaka (see Hishimoto (1938, pp.591,598)).

The rice from Korea was concentrated in Osaka because Korea is situated nearer Osaka in relation to Tokyo (see Ministry of Agriculture and Forestry, Rice Bureau (1938, p.2)). When it was shipped from Korea, farmers and brokers mixed sand, stones, and other trash into rice sacks to cheat their trading partners by commodity weight. Rice traders who dealt in Korean rice had to make an arrangement for polishing the rice with sand and stones. Accordingly, they inevitably prepared dedicated milling machines for the low-quality Korean rice to decontaminate sand and stones from the rice. Then, the dealers possessing the milling machines clustered in Osaka (see Hishimoto (1938, pp.571,598)). Finally we summarize the Korean rice trades in Japan at that time. First, the regional distribution of Korean rice in Japan was imbalanced. Second, the increase in rice import diversified the distribution of rice in Japan.

Unlike the actual rice distribution, rice futures continued to deal in domestic rice. The futures trading standard was domestic rice in both Tokyo and Osaka. In 1890, the Ministry of Agriculture and Commerce first forced both exchanges to accept imported rice as an alternative to deliverable rice. This intervention and other similar interventions were aimed at suppressing the futures rice price when Japan faced a serious shortage of rice. Then, the exchanges often permitted rice traders to deliver imported rice with a different quality than domestic rice.

After the Russo-Japanese War (1904–1905), the rice price continued to increase because Japan addressed the rice shortage aggressively. The government attempted to suppress rice price increases and forced the exchanges to accept imported rice as a deliverable regularly in 1912. During the same period, the Governor-General of Korea promoted japonica rice cropping in Korea. This policy had gradually reduced quality differences between domestic and Korean rice since the late 1910s.

The nationwide riots, *kome-soudou* (the Rice Riots), occurred in 1918, spurred by a serious rice shortage that had been triggered by the rising rice price. Reflecting on the disruption from the riot, the government began to intervene in the rice spot market and, in 1921, established the Rice Law. Article 1 of the Rice Law stated that if the government recognized the necessity to adjust rice supply and demand, it could buy, sell, change, process, and store the rice (see Ota (1938, p.332)). In short, the Rice Law allowed the government to buy and sell physical rice directly to adjust rice supply and demand. However, the government always intervened in the physical rice market by selling and buying only after estimating the supply and demand of rice (see Omameuda (1993, pp.198–201)). Then, in 1925, the government amended the Rice Law to overcome the above problem. Practically, the term “rice supply and demand,” in Article 1 was replaced by “the volume in circulation and price of rice” (see Ota (1938, pp.335–336)). That is, the government could flexibly respond to changes in price in the physical rice market. In the late 1920s, the Ministry of Agriculture and Forestry owned the physical rice in stock to reduce excessive volatility of rice price following the new Rice Law.¹

¹The Ministry of Agriculture and Commerce was separated into the Ministry of Agriculture and Forestry and the Ministry of Commerce and Industry in April 1925.

3 The Model

This section presents our econometric method used to examine the time-varying structure of the Japanese rice futures market in the Meiji, Taisho, and early Showa periods (1868 to 1945). The method is partly based on Ito et al. (2014b), who analyze the dynamic linkages of stock prices among G7 countries and the efficiency of the international stock market. However, our method focuses on the dynamic relation between the rice futures premium and the returns on spot rice in prewar Japan; we examine the time-varying estimates of the fundamental equation for the futures premium. Employing a non-Bayesian time-varying model approach, we conduct statistical inference for the time-varying estimates using a residual-based bootstrap technique.

3.1 Preliminaries

This paper considers the relation between the rice futures premium and the returns on spot rice. Following many earlier studies (e.g., Ito (1993) and Wakita (2001)), we adopt the fundamental equation for the futures premium as our starting point:

$$(\log S_{t+k} - \log S_t) = \alpha + \beta(\log F_{t+k|t} - \log S_t) + u_t, \quad (t = 1, 2, \dots, T - k), \quad (1)$$

where S_t is the spot price at time t , $F_{t+k|t}$ is the futures price at time t for delivery at time $t + k$, and u_t follows an independent and identically distributed process. That is, we consider the k -th period forward contract. This type of regression equation is typically employed to test the unbiasedness hypothesis in the context of financial market efficiency. In practice, the null hypothesis is that $(\alpha, \beta) = (0, 1)$ and $\{u_t\}$ are serially uncorrelated. Note that the hypothesis refers to the joint hypothesis of risk neutrality (or no-risk premium) and rationality. In other words, the hypothesis states that no informed speculators can expect to make excess returns (see Brenner and Kroner (1995) for details).

3.2 Non-Bayesian Time-varying Regression Models

Suppose that there is a concern for the time-varying structure of a possibly efficient futures market of the k -th period forward contract. The time series of spot returns $x_t = \log S_{t+k} - \log S_t$ and futures premiums $y_t = \log F_{t+k|t} - \log S_t$ should be examined. Note that x_t and y_t at t are theoretically considered an unknown futures return and its predictor. In practice, attention is given to the differences between the two variables $x_t - y_t$ at each time to study the time-varying predictive performance of futures. However, this approach does not make sense. Because $x_t - y_t = \log S_{t+k} - \log F_{t+k|t}$, time series of the differences would exhibit a nearly white noise process with small values at a high probability. The reason is that S_t and $F_{t+k|t}$ typically have a unit root, are highly correlated, and present spurious correlation. The above approach provides us with no information on the futures market.

We adopt another approach using Ito et al.'s (2014b) non-Bayesian time-varying model for Equation (1). This approach estimates the coefficients in Equation (1), possibly varying over time. Particularly, we use the following equation:

$$(\log S_{t+k} - \log S_t) = \alpha + \beta_t(\log F_{t+k|t} - \log S_t) + u_t, \quad (t = 1, 2, \dots, T - k). \quad (2)$$

This is a linear regression of the returns on spot rice on the rice futures premium. We consider whether β varies with time; we regard α as time-invariant considering its insignificance in the preceding works. Equation (2) cannot be estimated because it is unidentifiable. Thus, many preceding works estimating a model with time-varying parameters assume a dynamic equation with respect to such parameters, for example, random walk. We assume that β_t follows a random walk represented as follows:

$$\beta_{t+1} = \beta_t + v_t, \quad (t = 1, 2, \dots, T - k), \quad (3)$$

where each v_t follows an independent and identical distribution. We consider Equations (2) and (3) together as a state space model. Following Ito et al.'s (2014b), we employ a non-Bayesian technique to estimate the parameters in the state space model using time series of S_t and $F_{t+k|t}$ as data.² We consider Equations (2) and (3) together to estimate the parameters $\alpha, \beta_1, \dots, \beta_{T-k}$ by using the following matrix form:

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_{T-k} \\ \beta_0 \\ 0 \\ \vdots \\ 0 \end{pmatrix} = \begin{pmatrix} 1 & x_1 & & & \mathbf{O} \\ 1 & & x_2 & & \\ \vdots & & & \ddots & \\ 1 & \mathbf{O} & & & x_{T-k} \\ 0 & 1 & 0 & & \mathbf{O} \\ 0 & -1 & 1 & & \\ \vdots & & & \ddots & \ddots \\ 0 & \mathbf{O} & & -1 & 1 \end{pmatrix} \begin{pmatrix} \alpha \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_{T-k} \end{pmatrix} + \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_{T-k} \\ v_1 \\ v_2 \\ \vdots \\ v_{T-k} \end{pmatrix}, \quad (4)$$

where $x_t = \log S_{t+k} - \log S_t$, and $y_t = \log F_{t+k|t} - \log S_t$ for $t = 1, 2, \dots, T - k$. This helps us to estimate the coefficients and to conduct statistical inference using a bootstrap technique shown in the next subsection. We estimate the state vectors $(\alpha \ \beta_1 \ \beta_2 \ \dots \ \beta_{T-k})'$ at one time based on observations $x_1, x_2, \dots, x_{T-k}, y_1, y_2, \dots, y_{T-k}$ and a prior β_0 given by OLS or GLS that are familiar with economists. This vector estimate is identical to the Kalman smoother with a fixed interval of the corresponding state space model, Equations (2) and (3).³⁴

3.3 Statistical Inference for Time-varying Parameters

This subsection presents our methodology for statistical inference on the time-varying estimates of β_t 's in Equation (2). The idea is so simple that we examine the *estimates*

²See Ito et al.'s (2014b) Online Technical Appendix A.1, which is available at http://at-noda.com/appendix/inter_market_appendix.pdf for details.

³See Ito et al.'s (2016) Online Technical Appendix A.1, which is available at http://at-noda.com/appendix/evolution_appendix.pdf and Maddala and Kim (1998, ch.15) for details.

⁴Our method for estimating random parameter regression models is different from the method in the literature of the 1970s (see Swamy (1970), Swamy (1975) and Swamy and Tinsley (1980) for example). The latter study focuses on stationary stochastic coefficients such as an autoregressive moving average model (ARMA) process, whereas our study focuses on coefficients following a random walk, a non-stationary process.

with the joint distribution of our time-varying *estimator* $\hat{\beta}_1, \hat{\beta}_2, \dots, \hat{\beta}_{T-k}$ under the unbiasedness hypothesis that $\beta_t = 1$ for any t and $\alpha = 0$. After setting a significance level, for example, 95%, we construct upper and lower bounds based on the distribution as two time series: $\beta_1^U, \beta_2^U, \dots, \beta_{T-k}^U$ and $\beta_1^L, \beta_2^L, \dots, \beta_{T-k}^L$. Then, using a confidence band constructed from the two series of bounds, we examine in what period the estimates $\hat{\beta}_t$'s are inside the band to identify the periods of market efficiency.

However, we cannot employ an asymptotic theory to construct the confidence bands on time-varying coefficients that are supposed to follow a random walk. This difficulty stems from the asymptotes involved in a Brownian motion or Brownian bridge, and it is complex to derive them theoretically; their distributions can only be represented with some Brownian motion or Brownian bridge if it is successful. That is, such distributions require a Monte Carlo technique to conduct some statistical inference. We are obliged to adopt a residual-based bootstrap technique to construct parameter confidence bands of a state space model under the assumption of the unbiasedness hypothesis: $(\alpha, \beta_1, \dots, \beta_{T-k}) = (0, 1, \dots, 1)$ for our time-varying model. We consider the case where each β_t is estimated by the above method while the data are generated by Equation (1) when $(\alpha, \beta) = (0, 1)$.

In practice, our residual-based bootstrap technique consists of the following steps.⁵ First, we fit Equation (1) to the observed data. Then, we obtain a residual sequence $D_0 = (\hat{u}_1, \hat{u}_2, \dots, \hat{u}_{T-k})$. Second, we extract N bootstrap samples $D_i = (\hat{u}_1^{(i)}, \dots, \hat{u}_{T-k}^{(i)})$, $i = 1, 2, \dots, N$ with a replacement from D_0 considering it an empirical distribution of the residuals. Third, we generate N sets of $(\hat{u}_1^{(i)}, \dots, \hat{u}_{T-k}^{(i)})$ for $i = 1, 2, \dots, N$ using D_i for $i = 1, 2, \dots, N$. Fourth, we estimate N sets of the time-varying coefficients and their corresponding residuals by applying our time-varying model (4) to N bootstrap data $(x_1, x_2, \dots, x_{T-k}, y_1^{(i)}, y_2^{(i)}, \dots, y_{T-k}^{(i)})$ and a prior β_0 given for $i = 1, 2, \dots, N$. Finally, we construct a confidence band of $(\alpha, \beta_1, \dots, \beta_{T-k})$.

4 Data

We utilize the weighted average monthly data on the rice spot and futures prices in prewar Japan. For the rice futures data, three contract months of the Tokyo and Osaka rice exchanges are available: a nearby contract (one month), a second nearest contract (two months), and a deferred contract (three months). For the rice spot data, spot prices in Tokyo are on the Tokyo-Fukagawa rice spot market, and the spot prices in Osaka are the wholesale prices of rice in Osaka. These datasets consist of the following three statistics: (i) Nakazawa (1933) for all futures prices from October 1880 through November 1932, (ii) the *Tokyo City Statistics* and Ministry of Commerce and Industry (1931, p.342) for the spot prices in Tokyo from April 1881 through November 1932, and (iii) Miyamoto et al. (1979) and the *Osaka City Statistics* for the spot prices in Osaka from April 1881 through November 1932.⁶ There are a few missing values in both sets of statistics. Therefore, we

⁵See Ito et al.'s (2014b) Online Technical Appendix A.3, for which the basic idea is found in Lütkepohl's (2005) Appendix D.3.

⁶Note that the rice futures data of nearby and nearest contract months in Tokyo have different starting dates from the rice futures data of the deferred contract month. Particularly, the data for the

fill in the missing values using a seasonal Kalman filter. We take the first difference of the natural log of the spot rice prices to obtain the returns on spot rice, and we subtract the natural log of the spot rice prices from the natural log of the rice futures prices to calculate the rice futures premium.

(Table 1 around here)

From Table 1, we confirm that the longer the contract month, the more volatile the futures premium. The table also shows the results of the unit root test with descriptive statistics for the data. For our estimations, all variables that appear in the moment conditions should be stationary. To confirm whether the variables satisfy the stationarity condition, we apply the ADF-GLS test of Elliott et al. (1996). We employ the modified Bayesian information criterion (MBIC) instead of the modified Akaike information criterion (MAIC) to select the optimal lag length. This is because, from the estimated coefficient of the detrended series, $\hat{\psi}$, we do not find the possibility of size-distortions (see Elliott et al. (1996); Ng and Perron (2001)).

5 Empirical Results

5.1 Preliminary Results

We assume a time-invariant regression model with constant parameters for our preliminary estimations. Table 2 summarizes our estimation results for a time-invariant regression model for the whole sample: all estimates for α in Equation (1) are almost zero, and because the contract month of the rice futures is longer, the corresponding estimates of β are increasing. These results suggest that the longer the contract month, the more efficient the rice market in prewar Japan.⁷ Taketoshi (1999) obtains different estimates of β for each subsample when the whole sample is split into four subsamples. However, the author does not examine whether the rice market in prewar Japan is efficient using conventional statistical inferences. Therefore, we use Ito et al.’s (2016) non-Bayesian time-varying regression model to estimate the β because the rice market in prewar Japan may not always be efficient over time. However, we verify if the time-varying regression model is more appropriate than the time-invariant regression model before we adopt a new approach. Then, we apply Hansen’s (1992) parameter constancy test to investigate whether the time-invariant model is a better fit for our data.

(Table 2 around here)

Table 2 presents the results of our preliminary estimations: the estimates of time-invariant regression models (α and β) and their corresponding Hansen’s (1992) joint parameter constancy test statistics (L_C). For our time-invariant regression model, the joint parameter

nearby contract month are available from January 1888, and the data for the nearest contract month are available from January 1898.

⁷Note that our estimates of β are slightly larger than Taketoshi’s (1999) estimates because our dataset is seasonally unadjusted.

constancy test rejects the null hypothesis of constancy at the 5% level, against the alternative hypothesis stating that the parameter variation follows a random walk process. These results suggest that the time-invariant regression model does not accommodate our data; rather, we should use the time-varying regression model for the prewar Japanese rice market data.

5.2 *Time-varying Market Efficiency and Its Historical Interpretation*

Figures 1 and 2 show that the farthest contract month transaction is more efficient than the nearest and the next-nearest months in both the Tokyo and Osaka-Dojima rice exchanges.

(Figures 1 and 2 around here)

Time-varying market efficiency of the farthest contract month shows the same tendency as the next-nearest months. However, the longer the contract month (maturity) in futures, the more successfully traders hedged price risks in the rice market.

(Figures 3 and 4 around here)

Figures 3 and 4 show that the farthest contract month transaction was larger than any other futures transaction in both Tokyo and Osaka. The farthest contract month transactions amounted to approximately 70% of all futures in both rice exchanges. This suggests that the transaction successfully distributed required information to hedge price risks in the rice market in prewar Japan. Moreover, the time-varying market efficiency of the nearest contract month had a different nature than the next-nearest and farthest contract months in both Tokyo and Osaka (see Figures 1 and 2). This interesting feature of the rice futures exchanges in prewar Japan reflects that the exchanges provided settlement on the balance and delivery of physical rice to clear the nearest month transactions.

(Figure 5 around here)

Figure 5 shows the delivery volume for both Tokyo and Osaka. The figure indicates that the sellers constantly delivered physical rice to the buyers to clear their contracts in both cities. Taishichirou Tanaka, an administration officer of the Osaka stock exchange and a lecturer at Kobe College of Commerce, noted a characteristic of the nearest month transaction of rice in 1910. Tanaka stated, “The nearest contract month transaction of rice is not the speculative market, it is related in part to the spot trading.”⁸ According to his assertion, the nearest contract month transaction had two aspects: a financial market for rice brokers to hedge price risks and a delivery space for physical rice. Consequently, the delivery space aspect reduced the market efficiency of the futures trading.

Figures 1 and 2 show some periods when even the farthest contract month transaction in futures showed low market efficiency. Specifically, Figure 1 exhibits three such periods for the Tokyo rice exchange: the late 1880s, the late 1890s, and from the mid-1900s to the 1910s; Figure 2 exhibits three such periods for the Osaka rice exchange: the late 1880s, the late 1890s, and from the mid-1900s to the mid-1920s. The next section discusses why the farthest month transaction sometimes failed to hedge price risks in the rice market.

⁸See Tanaka (1910) for details.

5.2.1 Increasing Rice Exports from Japan in the Late 1880s

From 1885 to 1889, the amount of rice exported increased from 0.1 million *roku* to 1.3 million *roku*. The growing exports were a consequence of an upturn in trade conditions caused by a decreasing price for silver and a decrease in the price of Japanese rice in the international market. Under these conditions, the Japanese government became directly involved in rice exporting in 1883 to acquire specie money. In the late 1880s, the Japanese government bought rice at the spot market in western Japan and exported the commodity to Germany, Italy, the Netherlands, the UK, and the US (Ministry of Finance, Financial Bureau (1919, pp.161–166)). From 1887 to 1889, total rice exports amounted to three million *roku*. The amount of rice export by the government accounted for approximately 30% of all rice export in the late 1880s (see Omameuda (1993, p.20)). The expansion of rice exports caused the futures price of rice to change. Tokyo Asahi Shimbun (Tokyo Asahi Newspaper) addressed this state of affairs in 1888 as follows.

“In recent days, the rice price in futures increased while the rice harvest is plentiful. The main reason for this situation is that the market participants expect rice exports from Japan to increase because of the poor wheat harvest in Europe.”⁹

In short, the government-led expansion of rice exports disrupted the desired relation between spot and futures prices.

However, a population increase and a high growth rate in the big cities such as Tokyo and Osaka resulted in greater rice consumption after Japan experienced a serious rice failure in 1890. Then, rice exports rapidly decreased. In the early 1890s, it was possible to hedge rice price risks in the Tokyo and Osaka rice exchanges.

5.2.2 Increasing Rice Imports in the Late 1890s

In contrast to the case of the late 1880s, rice imports grew rapidly in the late 1890s.

(Figure 6 around here)

Figure 6 exhibits Japan’s rice consumption and imports from 1880 to 1932. The figure also shows that the ratio of imports to consumption began to increase from the 1890s. Imported rice from Indochina, cropped in Yangon and Ho Chi Minh, was categorized as the *indica* variety while domestic rice was categorized as the *japonica* variety. Thus, because of differences in texture and taste, Japanese consumers regarded such imported rice as an alternative grain. Consumers mixed domestic and imported rice in meal preparation (see Omameuda (1993, pp.37–40)). Both the Tokyo and Osaka-Dojima rice exchanges listed only two standard brands of rice as domestic rice, Musashi (rice cropped in Saitama prefecture) and Settsu (rice cropped in Hyogo prefecture). Ito et al. (2014a) showed that the most significant interventions responsible for low market efficiency from the year 1890 were often government orders that the exchanges should use imported rice as an alternative to the listed domestic rice in futures transactions. That is, the government

⁹See Tokyo Asahi Shimbun (1888) for details.

consistently argued that the commodity to be traded in the rice exchange was domestic rice. According to the government findings, when a significant difference in quality from rice traded in the futures and spot markets was identified, the futures market had no connection to the spot market.

However, the market efficiency estimated in this paper for the year 1890 is different from the estimation shown by Ito et al. (2014a). The difference between the market efficiency estimated in this paper and that of Ito et al. (2014a) stems from the data used in the two papers. We include the futures market and the spot market while Ito et al. (2014a) use monthly rice futures data only to examine the efficiency of rice futures markets from 1881 to 1932. The authors focus on the futures market ignoring the increasing volume of actual imported rice in the spot market. According to Figure 6, the ratio of imported rice to rice consumption in 1890 was below 4%. The ratio in 1890 was lower than the ratios in 1897 and 1898 when rice imports were higher again during the period after 1890. That is, in 1890, both the rice in the futures and spot markets was minimally different because imported rice was a minority portion of the physical rice distributed. Therefore, futures rice transactions in both Tokyo and Osaka were nearly efficient in 1890.

Figures 1 and 2 show that the market efficiency in the Osaka-Dojima rice exchange was lower than the market efficiency in 1890 in the Tokyo rice exchange. This result was caused by critical confusion in the same year in the Osaka-Dojima rice exchange. The Osaka-Dojima rice exchange opposed the government's order in 1890 to amend the trading rules that allowed imported rice to be delivered as an alternative to domestic rice. The Ministry of Agriculture and Commerce revoked the exchange's permission to trade in reaction to its disobedience. As a result, futures trading in Osaka stopped temporarily, and this critical confusion reduced market efficiency. The increasing volume of rice imports began to significantly reduce rice futures trading efficiency in the late 1890s. Figure 6 shows that the ratio of import to consumption increased rapidly in the late 1890s because Japan was hit by a record famine in 1897 (see Ota (1938, p.184)). In the Tokyo-Fukagawa rice spot market, the largest rice spot market in Japan, imported rice amounted to 43% of all physical rice in 1898 (see Sasaki (1937, pp.268–270)). In the same year, imported rice in year-end stock amounted to 54% of all inventory in the Osaka rice spot market (see Osaka-Dojima Rice Exchange (1915, pp.100–102)). These observations prove a significant difference in quality between rice traded in the futures market and the spot market. Imported rice was no longer the minority portion of rice distribution in the late 1890s. Rice market efficiency was reduced in this situation. At that time, the rice market in Japan traded in different grain because only domestic rice was listed in the futures market, and both imported and domestic rice was traded in the spot market. Only in 1898 did the government force the exchanges to accept the imported rice as a deliverable and an alternative to listed domestic rice. However, the futures price failed to be an accurate index of the expected price of rice in the late 1890s including 1898. In August 1898, Yomiuri Shimbun (Yomiuri Newspaper) addressed this situation as follows.

“Since the exchanges have agreed to deliver imported rice, the rice futures market depends on price fluctuations for imported rice. As a result, the trend

in rice futures price was different from that of the spot price.¹⁰

The grading system for delivered imported rice was different from the domestic rice system in the exchanges. The exchanges set up the sub-standard imported rice and changed the price difference between the grading of the sub-standard rice and imported rice. On the other hand, the price difference between standard domestic rice and sub-standard imported rice was basically fixed. However, the price difference between domestic and imported rice in the spot market was flexible. Therefore, this price difference in the futures market could not move with the difference in the spot market. Consequently, the market structure of rice futures was different from the structure of the rice spot market. In 1899, the ratio of rice imports to rice consumption decreased rapidly. However, this ratio began to skyrocket in 1902 and remained above approximately 5%. Japan had been a continuous importer of rice since the 1890s.

5.2.3 Difference in Structure Between the Spot and Futures Markets from the Mid-1900s to the Mid-1920s.

We discuss the market inefficiency from the mid-1900s to the mid-1920s. The market efficiency in both Tokyo and Osaka began to decrease in the mid-1900s. Tokyo Asahi Shimbun reported on the rice market in the late 1900s as follows.

“The price of imported rice was higher than coarse cereals, the price of domestic rice in the spot market was higher than imported rice, and the price of domestic rice in the futures market was higher than domestic rice in the spot market. The futures price was highest in the rice and grains market because most of the participants in the exchanges were speculators.”¹¹

That is, the price difference between the spot and the futures markets was caused by speculative rice trader dealings in the futures markets. However, there are two discrepancies in the market inefficiency between Tokyo and Osaka from the mid-1900s to the mid-1920s. First, the Osaka-Dojima rice exchange failed to provide an accurate index of the expected price of spot rice that was superior to Tokyo. Second, the period of market inefficiency in the Osaka-Dojima rice exchange is longer than Tokyo. The futures in the Tokyo rice exchange failed to provide a fine index of the expected price of spot rice from the mid-1900s to the 1910s. The Osaka-Dojima rice exchange experienced market inefficiency until the mid-1920s. The difference in market efficiency between Tokyo and Osaka was a consequence of the diversity in market structure characterized by the distribution of imported rice.

According to Figure 6, the volume of Japanese rice imports remained at a low level from 1899 to 1901, although that volume began to increase in 1902. Specifically, the ratio of imported rice to all physical rice arrived from 1901 to 1905 was 27% in the Tokyo-Fukagawa rice spot market and 23% in the Osaka rice spot market (see Osaka City Government (1903, pp.72–73); Osaka City Government (1906, pp.79 to 80); Osaka City Government

¹⁰See Yomiuri Shimbun (1898) for detail.

¹¹See Tokyo Asahi Shimbun (1907) for details.

(1907, pp. 87 to 88); Sasaki (1937, pp. 268 to 270)). Consequently, the market efficiency in both Tokyo and Osaka decreased in the early 1900s because the market structure of rice futures was different from the structure of the rice spot market (see Figures 1 and 2). This situation changed in the late 1900s.

The volume of Japanese rice imports in Japan began to decrease beginning in 1906 (see Figure 6). From 1905 to 1909, the ratio of imported rice to all physical rice arrived in Tokyo decreased to 22% while this ratio in Osaka increased to 27% (see Osaka City Government (1908, pp. 91 to 92); Osaka City Government (1909, pp. 163 to 164); Osaka City Government (1910, pp. 163 to 164); Osaka City Government (1911, pp. 253 to 254); Sasaki (1937, pp. 268 to 270)).¹² This asymmetric situation between Tokyo and Osaka was caused by an increase in imported rice from Taiwan and Korea. From 1905 to 1909, the import volume of Taiwanese rice increased from 0.7 million *koku* to 1.2 million *koku*, and the import volume of Korean rice increased from 0.1 million *koku* to 0.5 million *koku* while the volume of foreign rice imports decreased from 2.6 million *koku* to 0.9 million *koku* (see Ministry of Agriculture and Forestry, Rice Bureau (1933, pp. 3 to 4)). To sum up rice imports in the late 1900s, the volume of all rice imports decreased along with the import volume of foreign rice, whereas Taiwanese and Korean rice imports increased.

The major destination port of Taiwanese and Korean rice in Japan was the port of Kobe. When the rice from Taiwan and Korea arrived at Kobe, barge clusters transported Taiwanese and Korean rice to the nearby port of Osaka, which was almost nine miles (15 kilometers) away (see Ichinohe (1920, pp. 561)). Taiwanese and Korean rice differed in quality from domestic rice. Taiwanese and Korean rice was categorized as the indica variety as was the imported rice from Indochina. Taiwanese rice varied considerably in quality because the rice farming method in Taiwan was double cropping (see Ministry of Agriculture and Forestry, Rice Bureau (1938, pp. 27)). Korean rice was mixed with sand, stone, and other trash (see Hishimoto (1938, pp. 598)). Korean rice was concentrated in Osaka because the rice traders could decontaminate the trash from Korean rice clustered in Osaka (see Ministry of Agriculture and Forestry, Rice Bureau (1938, pp. 2)). Osaka Asahi Shimbun reported, “In Osaka, rice traders have excellent sales for Taiwanese rice because its demand has increased.”¹³

However, rice exchanges could not trade the imported rice. In the late 1900s, both the standard and deliverable commodities in the exchanges were domestic rice only. Therefore, the structure of the futures market differed from the spot market. In the late 1900s, market efficiency was reduced only in Osaka because the ratio of imported rice to all physical rice arrived in Osaka increased. As a practical measure, Tokyo Asahi Shimbun urged the government to shrink the market structure differences between the spot and the futures.¹⁴ Although the government forced the exchanges to accept imported rice from Taiwan and Korea as an alternative to deliverable domestic rice in June 1912, the futures price in both Tokyo and Osaka failed to be an accurate index of the expected price in the rice spot market in the 1910s.

¹²The ratio of imported rice to all physical rice arrived in the Osaka rice spot market does not include the data for 1902, 1903, and 1908 because there are no statistics.

¹³See Osaka Asahi Shimbun (1909) for details.

¹⁴See Tokyo Asahi Shimbun (1911) for details.

The inefficiency resulted from the persistent differences in structure between the spot and the futures markets. A greater amount of imported rice had been traded in the spot market since the 1910s. From 1903 to 1918, the volume of domestic rice production increased to 17.7%. In the same period, total population and the urban population with over 100,000 inhabitants increased to 20.2% and 63.1%, respectively (see Bank of Japan, Statistics Department (1966, pp. 12, 14, 108)). Japan faced a rice shortage because its population growth was greater than its increase in rice production. Japan was forced to compensate for the rice shortage with rice imports. In the 1910s, the ratio of import volume to consumption fluctuated wildly. The ratio increased sharply from 1912 to 1913 and from 1917 to 1919 (see Figure 6).

(Figures 7 and 8 around here)

The ratio of imported rice to all physical rice arrived in both Tokyo and Osaka had a similar tendency as the ratio of import volume to consumption. However, the ratio of imported rice to all physical rice arrived in Osaka showed a different propensity to that of Tokyo in the early 1910s. The ratio of imported rice to all physical rice arrived in Osaka continued to increase to approximately 50% until 1915 while the rate in Tokyo reached a peak in 1913 and remained approximately 40% until 1915. This asymmetric trend between Tokyo and Osaka was caused by an increase in the volume of Korean rice imports under the same conditions in the late 1900s. From 1912 to 1915, the volume of Korean rice imports increased from 0.2 million *koku* to 19 million *koku*, and the volume of foreign rice imports decreased from 20 million *koku* to 0.5 million *koku* (see Ministry of Agriculture and Forestry, Rice Bureau (1933, pp. 3 to 4)). The increase in the volume of Korean rice imports led to a swelling in the volume of rice arrived from overseas in Osaka. In Osaka prefecture, the volume of imported rice arrived increased from 0.2 million *koku* in 1912 to 0.9 million *koku* in 1915 with an increase in the volume of Korean rice arrived from 0.2 million *koku* to 0.7 million *koku* for the same period (see Ichinohe (1920, pp. 420)).

In the late 1910s, market efficiency temporarily improved from 1916 to 1917. This was because the difference in market structure between the spot and the futures had shrunk along with the ratio of imported rice to all physical rice arrived in both Tokyo and Osaka (see Figures 1, 2, 7, and 8). After that, Japan faced a serious rice shortage from 1918 to 1919. The nationwide riots, *kome-soudou* (the Rice Riots) in 1918, were a response to the shortage. At the same time, the ratio of imported rice to all physical rice arrived in both Tokyo and Osaka surged. From 1912, the government forced the exchanges to accept imported rice from Taiwan and Korea as an alternative to listed domestic rice. However, the differences between the spot and futures markets remained.

Kawai Yoshinari, Director of the Division of Foreign Rice Management at the Ministry of Agriculture and Commerce and responsible for controlling the rice market to stabilize prices and transactions, stated that the fixed price difference in the exchanges between the standard domestic rice and sub-standard imported rice was smaller than the flexible price difference in the spot market between domestic and imported rice. Therefore, rice traders considered Korean and Taiwanese rice more desirable for delivery in the rice exchanges than sale in the spot markets. In 1921, Yoshinari reviewed the situation of futures trading in the 1910s as follows.

“At the maturity date in the exchanges, many sellers tended to use Taiwanese rice as the rice for delivery. As a result, the futures price fell. However, the price difference between the spot and the futures did not shrink at the maturity date. The futures market showed hardly any relationship with the spot market because the rice futures market strongly depended on the price of rice from Taiwan and Korea.”¹⁵

In the 1910s, the differences in structure between the spot and the futures markets remained because of the failure of the imported rice grading system in the exchanges.

In the early 1920s, the turmoil in the rice markets settled. In the same period, the volume of imported rice arrived in Tokyo decreased and the ratio of imported rice to all physical rice arrived remained below 30% (see Figure 7). For Osaka, the major destination of Taiwanese and Korean rice, the volume of imported rice arrived increased, and the ratio of imported rice to all physical rice arrived remained over 50% (see Figure 8). Asahi Shimbun reported that the Osaka-Dojima rice exchange failed to provide an accurate index of the expected price in the spot market in the early 1920s. Shimbun stated, “The futures market in Osaka was disrupted because 440,000 *koku* of Korean rice was stored in the city of Osaka. Additionally, the large amount of Korean rice was stored around Osaka.”¹⁶

Therefore, while the market efficiency improved in Tokyo, efficiency decreased in Osaka, reflecting the asymmetric situation between Tokyo and Osaka.

5.2.4 Improving Market Efficiency in the Late 1920s

In the late 1920s, Tokyo and Osaka futures provided an accurate index of the expected price of spot rice. The reasons for the improvement in efficiency were two-fold. First, the rice cultivated in Taiwan and Korea changed in quality. Second, government-owned physical rice increased after the late 1920s. The next section discusses these two factors.

With respect to the changes in Taiwanese and Korean rice, a newspaper published in June 1924 reported that the quality differences between domestic and Korean rice had shrunk.

“In June 18, the Society of Housewives held a rice tasting event in Tokyo. About 70 people from the Tokyo Metropolitan Government, the Ministry of Agriculture and Commerce, the Bank of Korea, the Oriental Development Company (Toyo Takushoku Company), and so on were invited to the event. The participants tasted the domestic rice and the Korean rice. They tried to guess which Korean rice was in all the samples. However, only five of them, who were the experts on rice trading, guessed Korean rice exactly.”¹⁷

After the 1910s, the Governor-General of Korea promoted rice cropping of the domestic rice variety. The ratio of the domestic rice variety to the total rice production in Korea was

¹⁵See Kawai (1921) for details.

¹⁶See Tokyo Asahi Shimbun (1924c) for details.

¹⁷See Tokyo Asahi Shimbun (1924b) for details.

only 5% in 1912, 69% in 1921, and 79% in 1932 (see Tohata and Okawa (1939, pp. 438 to 439)). Additionally, following Korea, the Governor-General of Taiwan introduced japonica rice cropping in 1924 (see Governor-General of Taiwan (1945, pp. 244)). Since the introduction of japonica rice cropping to Korea and Taiwan, rice cropped in the Japanese colonies had represented the majority of imported rice in Japan. From 1920 to 1930, the changes in Korean, Taiwanese, and foreign rice import volumes and their ratio to total rice imports were as follows: the import volume of rice from Korea increased from 1.7 million *koku* to 5.2 million *koku*, Taiwanese rice import volume increased from 0.7 million *koku* to 2.2 million *koku*, and foreign rice import volume increased from 0.8 million *koku* to 1.2 million *koku*. Each change in ratio was from 54.4% to 60.1%, from 21.8% to 25.4%, and from 24.7% to 14.5% in the same order (see Ministry of Agriculture and Forestry, Rice Bureau (1933, pp. 4 to 5)). This implies that the proportion of the imported rice categorized as the indica variety arrived in the rice spot market rapidly decreased. Thus, imported rice had a minimal effect on rice pricing in the rice futures market and the spot market even under conditions of a large amount of imported rice. The exchanges shrank the price difference in the grading system between sub-standard imported rice and standard domestic rice delivery after 1925.¹⁸

In summary, the changes in rice variety cropped in Korea and Taiwan allowed inland populations to consume more imported rice; it also led to better hedging of price risk in the rice exchanges.

We discuss the second factor of efficiency improvements in the late 1920s. With respect to the increase in physical rice owned by the government in the late 1920s, the Japanese government established the Rice Law in 1921 and amended that law in 1925. The amended law allowed the government to buy and sell physical rice directly to adjust the circulation volume and the rice price. Specifically, the Ministry of Agriculture and Forestry had owned the physical rice in stock since 1925 to adjust the volume of circulation in the rice market. The stock rice owned by the government amounted to one million *koku* in 1925 and reached 2.3 million *koku* in 1931 (see Ministry of Agriculture and Forestry, Rice Bureau (1935, pp. 4 to 5)). This volume in 1931 accounted for 3.5% of total rice demand in Japan and equaled nearly 44% of the annual volume of rice arrived in Tokyo (see Figures 6 and 7). From the mid-1920s, government intervention based on the Rice Law and the change in the variety of imported rice from Korea and Taiwan stabilized the supply and demand of rice in the home islands of Japan. This implies that the price risk in the rice market decreased. However, the seasonality price risk remained. According to Figures 3 and 4, trading volume in both the Tokyo and Osaka-Dojima rice exchanges experienced seasonal fluctuations from the mid-1920s. The trading volume increased in harmony with the expansion of rice distribution in the fall harvest seasons from the mid-1920s. Therefore, market efficiency in both Tokyo and Osaka improved after the mid-1920s. However, market efficiency in Osaka was relatively lower than the market efficiency in Tokyo. The difference in market efficiency between Tokyo and Osaka reflected the difference in their market structures.

After the late 1920s, the ratio of imported rice to all physical rice arrived in Osaka was approximately 80% while the corresponding ratio to Tokyo was approximately 30%

¹⁸See Tokyo Asahi Shimbun (1924a) for details.

(see Figures 7 and 8). In short, imported rice had occupied the central position in the rice spot market in Osaka in contrast to Tokyo. Korean rice, which accounted for a large part of imported rice in Osaka, was of the same variety as domestic rice, but the price of rice cropped in Korea was lower than domestic rice. For example, the prices per *koku* of domestic and Korean rice in Osaka in 1931 were 18.15 yen and 17.29 yen, respectively. That is, consumers did not consider Korean rice to be the equivalent of domestic rice. This suggests that the differences in market structure between the spot and the futures markets reduced market efficiency.

6 Conclusion

This paper argues that a difference in market structure between spot and futures caused the functional decline of rice futures markets that were supposed to provide efficient forecasts of the rice spot price in prewar Japan. This paper also argues that direct government intervention in the markets failed to improve the decline while indirect intervention through a change in the variety of colonial rice improved the function of rice futures. Particularly, the difference was caused by rice futures markets' exclusive activity in domestic rice, whereas imported rice of a different variety represented a greater proportion of rice distribution in Japan.

The government intervened in rice futures exchanges to shrink the difference. The government forced the major exchanges in Tokyo and Osaka to allow the imported rice deliverable. However, the intervention practically fixed the differences between the prices in domestic and imported rice in the futures markets. The corresponding difference in the spot rice markets could not be adjusted and failed to improve the functioning of the rice futures markets.

However, when the Japanese colonial government promoted japonica rice cropping in the 1910s, market improvements occurred. The promotion shrank the differences in quality between domestic and imported (Korean and Taiwanese) rice that was distributed in Japan and the differences in structure between spot and futures markets. Finally, the rice futures markets regained their functioning.

In summary, the increased volume of imported rice of a different variety from domestic rice first disrupted the rice futures in prewar Japan. Then, government intervention in the rice futures exchanges failed to improve the disruption. Changes in colonial rice cropping successfully improved the disruption, and colonial rice was promoted to unify the different varieties of inland and colonial rice. The function of rice futures markets crucially depended on the differences in rice spot markets' structure.

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Table 1: Descriptive Statistics and Unit Root Tests

	Tokyo						Osaka					
	One Month		Two Month		Three Month		One Month		Two Month		Three Month	
	SR	FP	SR	FP	SR	FP	SR	FP	SR	FP	SR	FP
Mean	0.0025	-0.0172	0.0015	-0.0172	0.0024	-0.0176	0.0013	-0.0227	0.0027	-0.0212	0.0042	-0.0201
SD	0.0536	0.0688	0.0908	0.0822	0.1145	0.0902	0.0619	0.0789	0.0923	0.0920	0.1171	0.1045
Min	-0.3670	-0.3623	-0.4601	-0.3600	-0.5360	-0.3549	-0.2939	-0.3780	-0.3821	-0.5279	-0.4582	-0.5991
Max	0.2791	0.1769	0.3116	0.2037	0.4752	0.1618	0.6569	0.2190	0.7260	0.3132	0.8131	0.2494
ADF-GLS	-16.1633	-6.9630	-4.2744	-5.8867	-6.6164	-7.9606	-13.8955	-8.8637	-5.7255	-7.9995	-4.8899	-7.5746
Lags	0	0	8	0	10	1	1	0	8	1	2	18
$\hat{\phi}$	0.3442	0.8317	0.7294	0.8444	0.7843	0.8629	0.1968	0.7739	0.6053	0.7220	0.7153	0.7657
\mathcal{N}	538		417		624		619		618		617	

Notes:

- (1) “ADF-GLS” denotes the ADF-GLS test statistics, “Lags” denotes the lag order selected by the MBIC, and “ $\hat{\phi}$ ” denotes the coefficients vector in the GLS detrended series (see equation (6) in Ng and Perron (2001)).
- (2) In computing the ADF-GLS test, a model with a time trend and a constant is assumed. The critical value at the 1% significance level for the ADF-GLS test is “-3.42”.
- (3) “ \mathcal{N} ” denotes the number of observations.
- (4) R version 3.2.3 was used to compute the statistics.

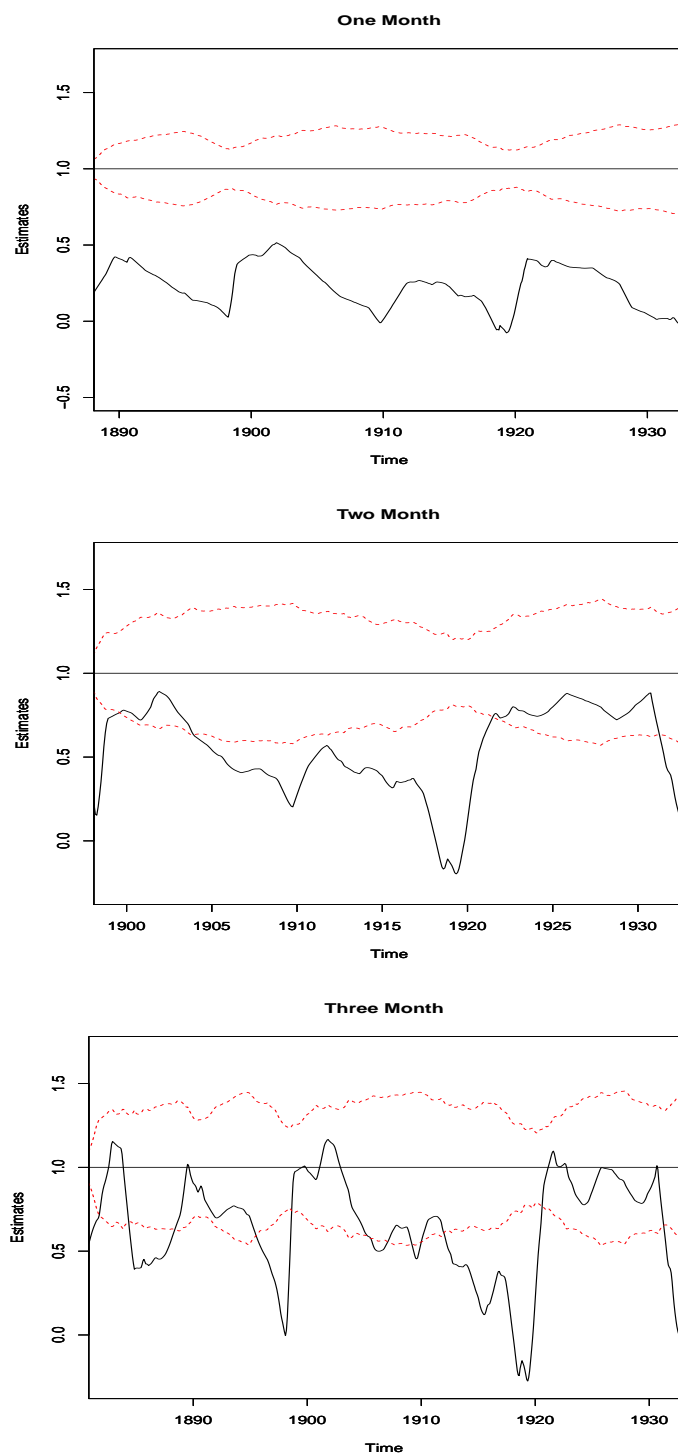
Table 2: Time-invariant Estimations

	Tokyo			Osaka		
	One Month	Two Month	Three Month	One Month	Two Month	Three Month
α	0.0056 [0.0028]	0.0066 [0.0096]	0.0118 [0.0085]	0.0076 [0.0030]	0.0100 [0.0058]	0.0119 [0.0106]
β	0.1771 [0.0743]	0.2927 [0.1682]	0.5298 [0.1572]	0.2771 [0.0435]	0.3424 [0.0693]	0.3823 [0.1023]
R^2	0.0500	0.0679	0.1728	0.1232	0.1150	0.1149
L_C	1.0740	1.0510	1.6171	1.5787	1.8331	2.4301

Notes:

- (1) “ \bar{R}^2 ” denotes the adjusted R^2 , and “ L_C ” denotes Hansen’s (1992) joint L statistic with variance.
- (2) Newey and West’s (1987) robust standard errors are in brackets.
- (3) R version 3.2.3 was used to compute the estimates and the statistics.

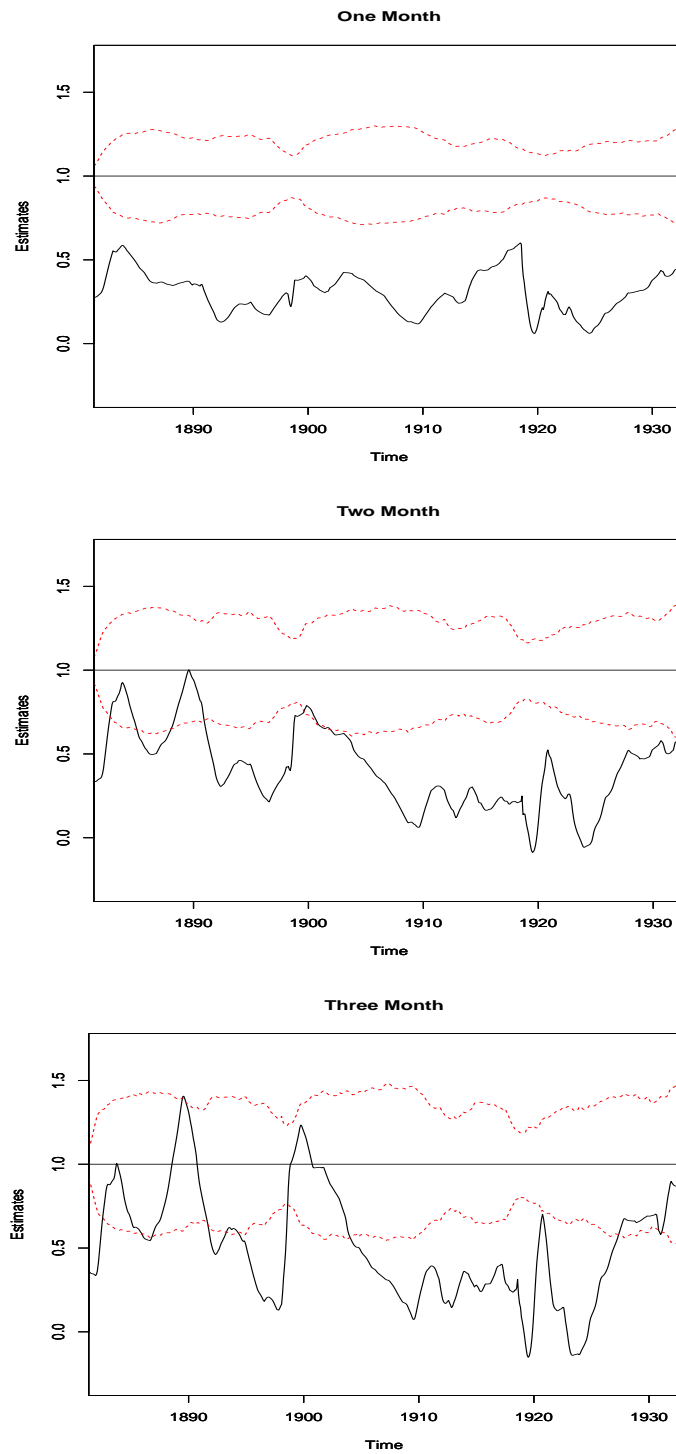
Figure 1: Time-varying Estimates of β : The Case of Tokyo Rice Market



Notes:

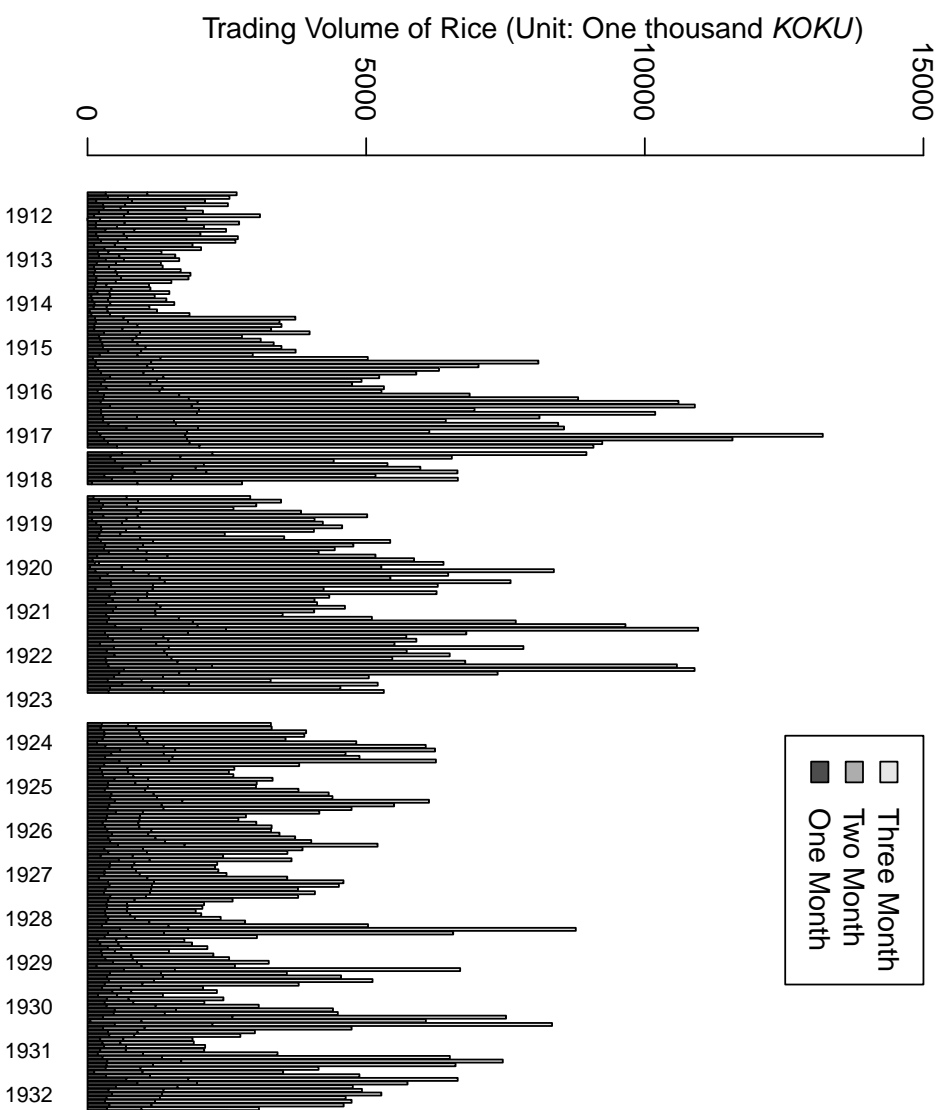
- (1) The dashed red lines represent the 95% confidence bands of the estimates in the case of an efficient market.
- (2) We run 5000 times bootstrap sampling to calculate the confidence bands.
- (3) R version 3.2.3 was used to compute the estimates.

Figure 2: Time-varying Estimates of β : The Case of Osaka Rice Market



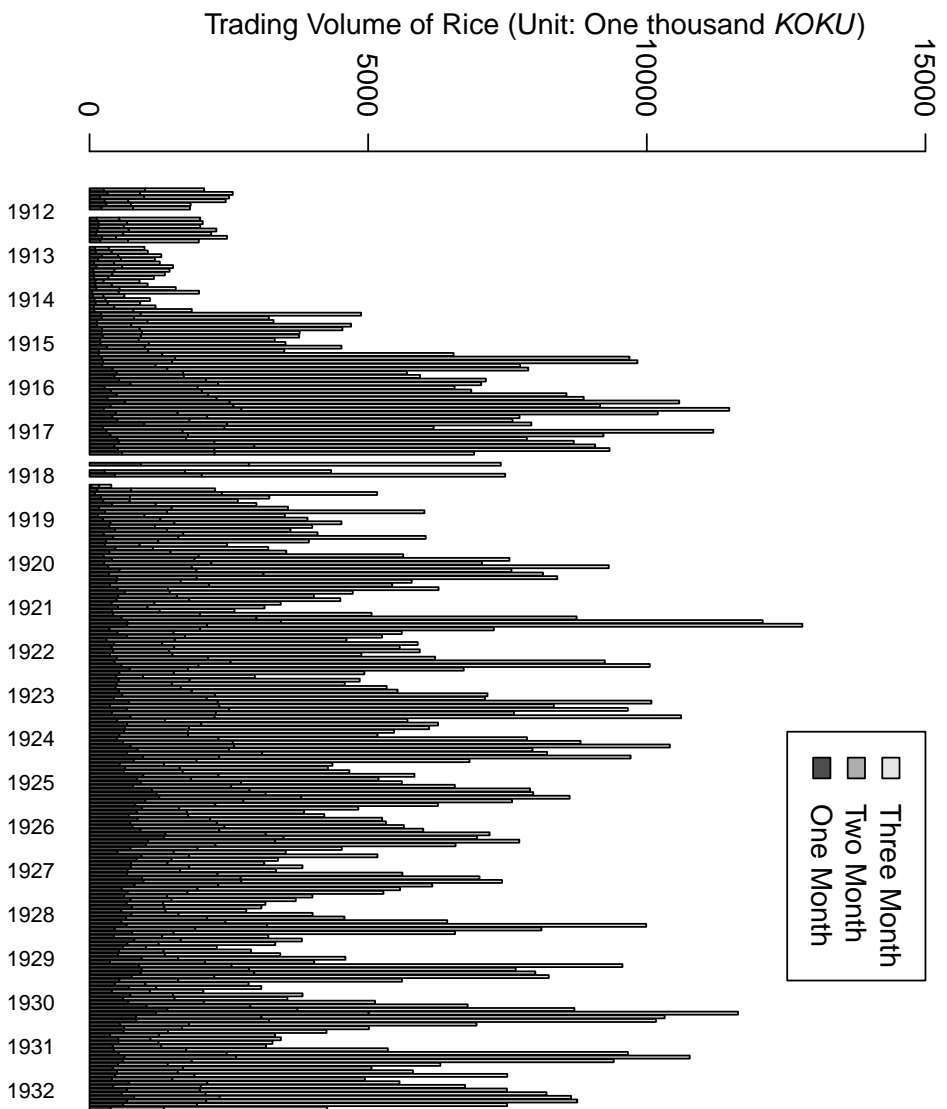
Note: As for Figure 1.

Figure 3: Trading Volume of Rice in Tokyo Rice Exchange



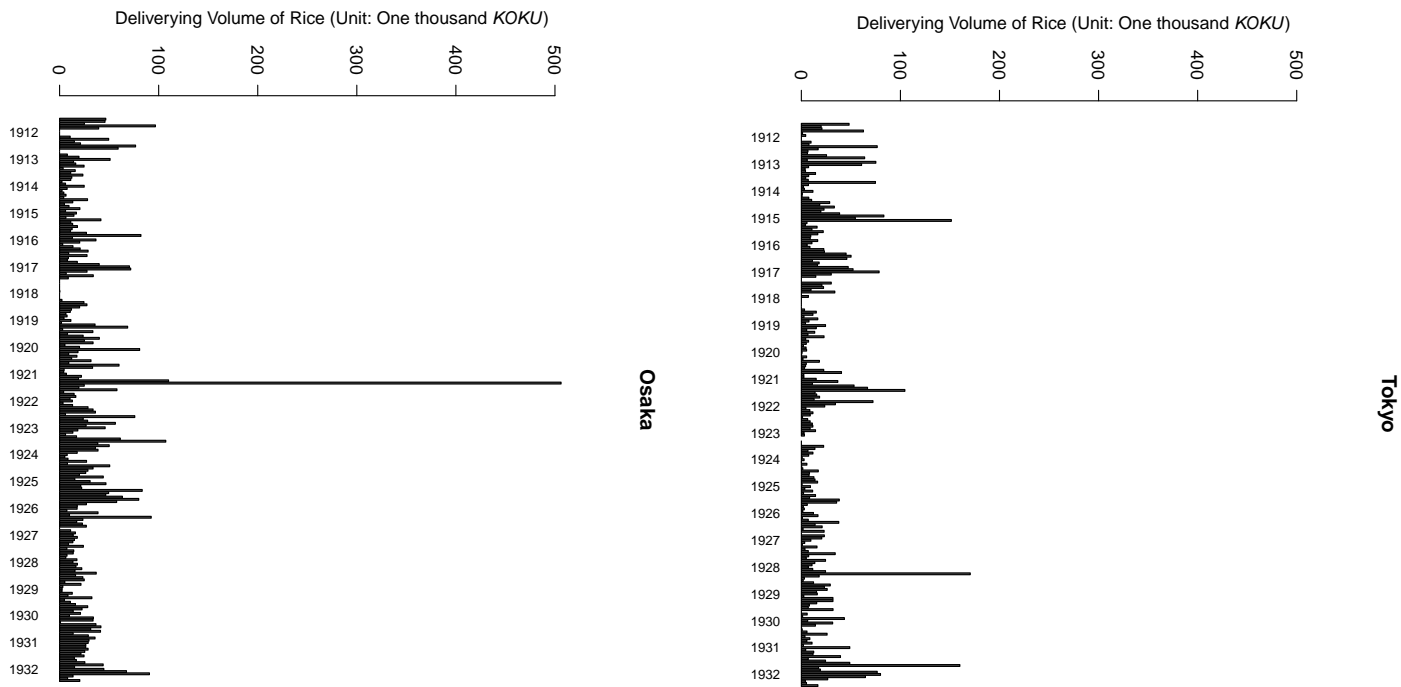
Data Source: Ministry of Agriculture and Forestry, Rice Bureau (1935c).

Figure 4: Trading Volume of Rice in Osaka-Dojima Rice Exchange



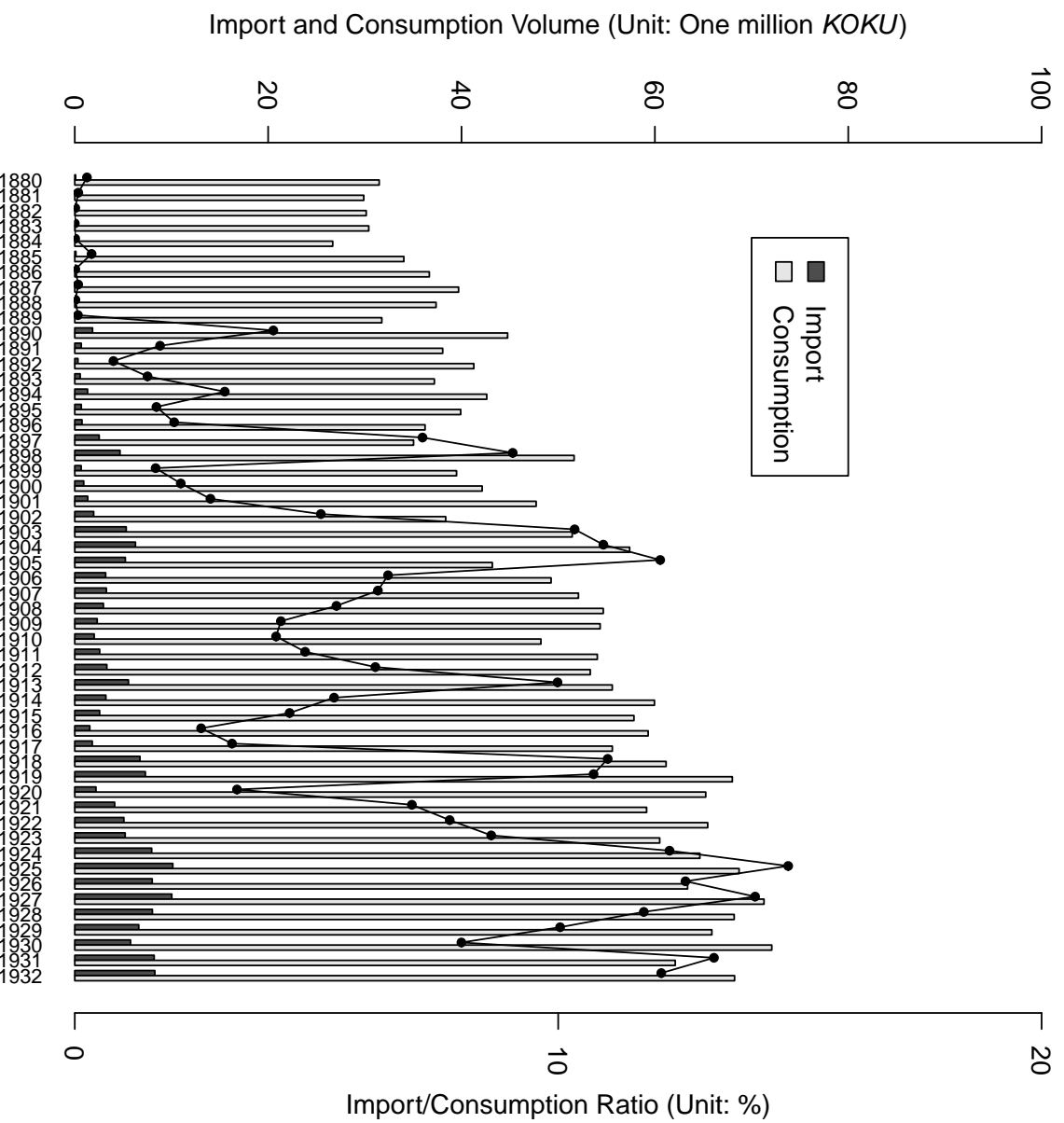
Data Source: Ministry of Agriculture and Forestry, Rice Bureau (1935a).

Figure 5: Delivery Volume in Tokyo and Osaka-Dojima Rice Exchanges



Data Sources: Ministry of Agriculture and Forestry, Rice Bureau (1935a,b,c).

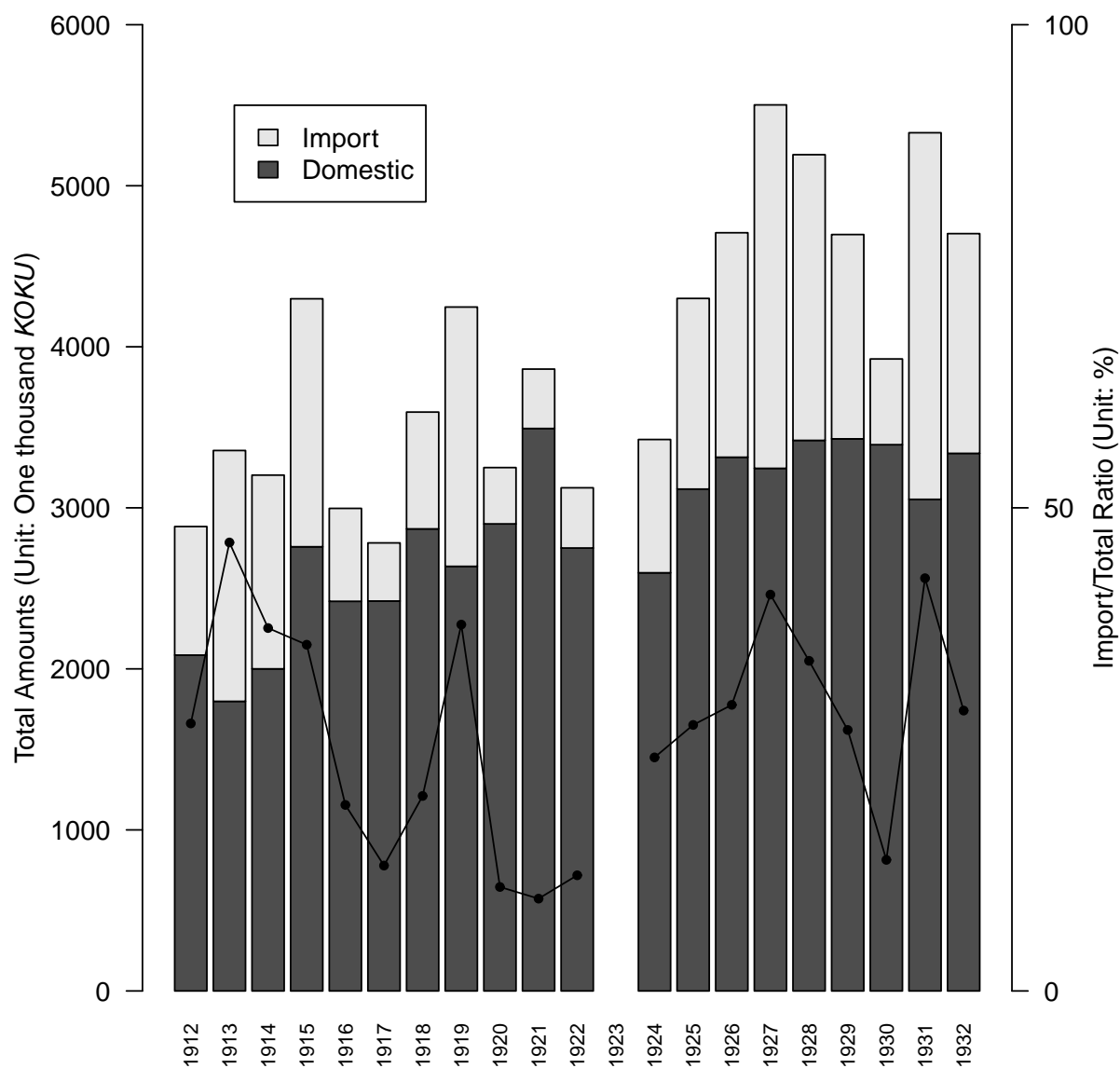
Figure 6: Consumption and Import Volume of Rice in Japan (1880 to 1932)



Data Sources:

- (1) Toyo Keizai Shimpo Sha (1935, pp.5,154,485,504,592).
- (2) Bank of Japan, Statistics Department (1966, pp.108–109).

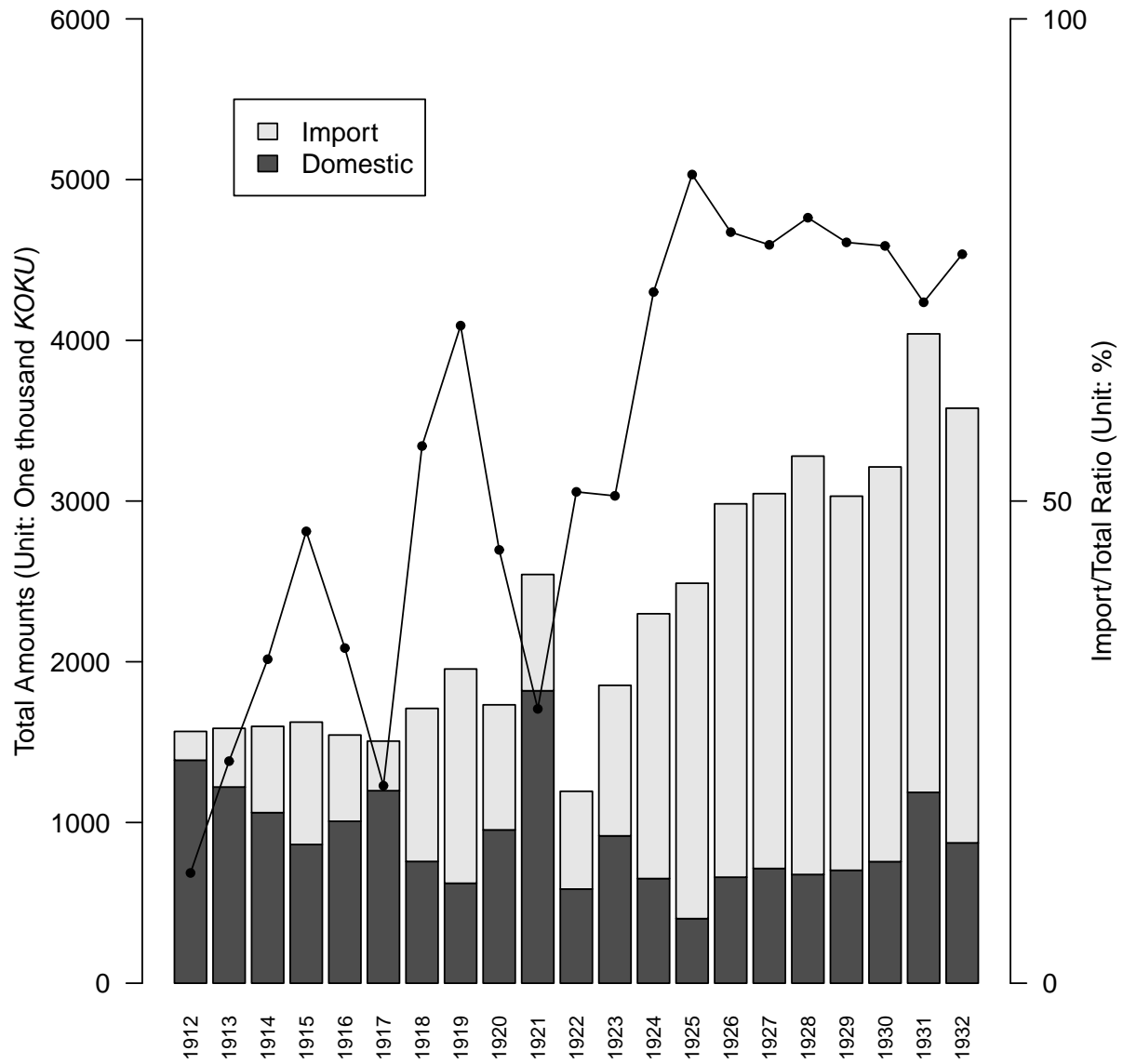
Figure 7: Total Amounts of Rice Arrived in Tokyo (1912 to 1932)



Notes:

- (1) The dataset is obtained from Sasaki (1937, pp.273,281-282).
- (2) There are no statistics presenting for the amount of rice arrived in 1923 because the Great Kanto Earthquake occurred in Tokyo in September 1923.

Figure 8: Total Amounts of Rice Arrived in Osaka (1912 to 1932)



Data Sources:

- (1) Osaka City Government (1919, ch.7, p.44).
- (2) Osaka City Government (1925, ch.7, pp.854–855).
- (3) Osaka City Government (1933, ch.5, pp.34–35).